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Freeze-Dried Foods and the Frozen Food Industry

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Freeze-drying has advanced beyond the realm of the laboratory and test tube. It is now in the evolutionary stage of market testing. For example, a prominent cereal manufacturer is presently conducting market tests of freeze-dried strawberries and corn flakes in Columbus, Ohio. Next month this company will be testing on the west coast a cereal combination of freeze-dried prunes and bran flakes. In the Midwest a dairy company is market testing freeze-dried cottage cheese. A dozen or more other companies are testing a range of new foods.

Although not what we would call a full-fledged processing industry, freeze-drying is growing in that direction. In this country, there are about 10 processors drying by sublimation, in Canada there are several more, and in the rest of the world about 23 other plants are in production. Several freeze-drying plants are now being built in the United States, and about five are under construction abroad, including one in Japan and one in Brazil. 2/

With this flurry of activity in freeze-drying there is cause for concern among freezers, frozen food distributors, owners of retail

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1/ Prepared for release to the Maryland Frozen Food Locker Association annual meeting, September 18, 1963. Additional free copies may be obtained from the Division of Information, Office of Management Services, U.S. Department of Agriculture, Washington D.C. 20250.

2/ For a complete listing of freeze-dried processors and equipment manufacturers see "A Directory of Freeze-Drying," F-D Report No. 4, April 1963. This is free and available from the Division of Information.

stores, locker plant managers, and others in the frozen food business. Conjectures are being made concerning the impact of this process on the frozen food industry, and questions such as these are asked: (1) How do freeze-dried foods compare with frozen ones in palatability? (2) What are the costs of freeze-dry processing? (3) How might freeze-drying affect the frozen food industry?

Is the picture so black as some picture it? Swinburne said, "This I ever held worse than all certitude, to know not what the worst ahead might be." Let's look into what we actually know about freeze-drying and see what the worst might be, in so far as the way the frozen food industry may be affected.

Before we get too deeply involved in looking at the trees, let's look at the forest by first defining the process of freeze-drying, examining its advantages and disadvantages, and discussing some of the products now being dried. Then we can look at the markets of these newly-developed foods and make some reasonable estimates as to how the frozen food industry may be changed as a result of freeze-drying.

Freeze-drying is the process of removing moisture from a frozen food without melting it. This is called sublimation. It is done in a room, cabinet, or chamber where heat is applied to the food as low pressures remove the water vapor. The food is kept frozen during the process. This sounds simple, and from a theoretical point of view, it's easy to understand. However, it takes a lot of practical know-how to get the right combination of temperatures and pressures to insure a high-quality product. At the culmination of drying it's a dried product. Moisture at the end of the process is about 2 percent.

Actually the food goes through some processing even before being dried. Much of the food now being freeze-dried is precooked, although not all. Then it is diced, pulverized, or sliced. Next it is quick-frozen in the usual manner before being placed in the sublimation chamber. When finished drying, the food is removed from the chamber and placed in some kind of moisture and oxygen-proof container such as a can or foil-laminate package. Packaging is one of the major problems of the industry since a good wrap is essential but expensive.

The advantages of freeze-drying are that the product produced is quite superior to most foods dried by other drying methods such as sun, spray, roller, or other heat-drying methods. With certain foods this new technique is not greatly superior to other drying methods, but in general freeze-dried foods retain their shape better, rehydrate more easily and quickly, and retain color, texture, and nutrients to a higher degree than food from other drying techniques. This food form minimizes shipping, handling, and storing costs since the water content is so low. The end product is a stable material suitable for room temperature storage for periods of about 2 years.

The disadvantages of freeze-drying are that, compared with frozen or canned foods, processing costs are high. This is because the food has first to be frozen, then freeze-dried processed, and then canned or otherwise packaged. Thus, it has an additional processing step which is fairly expensive. We'll discuss processing costs later. Then too, freeze-drying does not produce foods that have quite the quality of frozen foods. Of course, it is the food quality that the consumer uses that counts. Freeze-dried foods may be superior to frozen foods, if the

frozen foods happen to have been mistreated during or after processing.

Another limitation of freeze-dried foods is their appearance when dry. To the extent that appearance of a food is associated with moisture in the product, that food appears quite unappetizing while in the dry state. However, these foods are eaten after being rehydrated, so appearance may be only a minor drawback. Fragility is something of a problem since these foods are friable and crumble easily. A package must be designed to offer protection during shipping and handling.

The major markets for freeze-dried foods are the military, the institutional, and the manufacturing market. To date the armed services have been the largest buyer of these foods. They use these foods in regular mess menus and have plans for using them in emergency or combat-type foods.[7] Generally the institutional market is more progressive than the retail market, in so far as innovations are concerned, and this may be true of freeze-dried foods. I expect the institutional market to use these dried foods in substantial volumes.

In my personal opinion, the manufacturing market is the largest volume market for freeze-dried foods of the future. Here I am thinking of freeze-dried items to be used with other ingredients. An example would be meats or vegetables in soups, stews, or dinners. Or it might be fruits to be used in gelatin desserts, puddings, breakfast cerals, cake mixes, or prepared salads. Another example might be freeze-dried coffee extract to be blended with spray-dried coffee extract, or freeze-dried tea added to other instant teas. Most of these foods will get to the home of the consumer but in a disguised form. For example, freeze-dried soups currently manufactured make no mention on the package

of the method of processing. Actually, there is little need to mention freeze-drying to consumers, since they are not particularly interested in processing techniques, only in suitable products at satisfactory prices.

The retail market for freeze-dried items, sold individually as such, is small and still in the future. Freeze-dried items will have a difficult time penetrating the retail market since to do so they need something unique to offer in terms of product quality, price, or convenience. Most freeze-dried foods have few of these attributes, except for their storage aspects. They do have novelty, but this provides no incentive for repeat sales. Of the items to enter the retail market in recent months, freeze-dried mushrooms have created the greatest interest. I predict a good future for this food.

In addition to the major markets, there are specialty markets, as for example the camping one. This is small and limited to campers needing light weight and the nonperishability of dried foods combined with the high quality formerly found only in frozen or canned foods. Incidentally, campers using freeze-dried foods must be willing to pay for the convenience they get. Camper food items are expensive and not suited to most people who have found camping an inexpensive way of taking a vacation.

Quality of Freeze-Dried Foods as Compared with Frozen Foods.

This year we released results of our taste tests of freeze-dried foods. 3/ The taste comparisons of freeze-dried foods discussed here

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3/ See "Freeze-Dried Foods: Palatability Tests," Kermit Bird, Marketing Research Report 617, July 1963. Free copies available from Division of Information, Office of Management Services, USDA, Washington, D.C. 20250

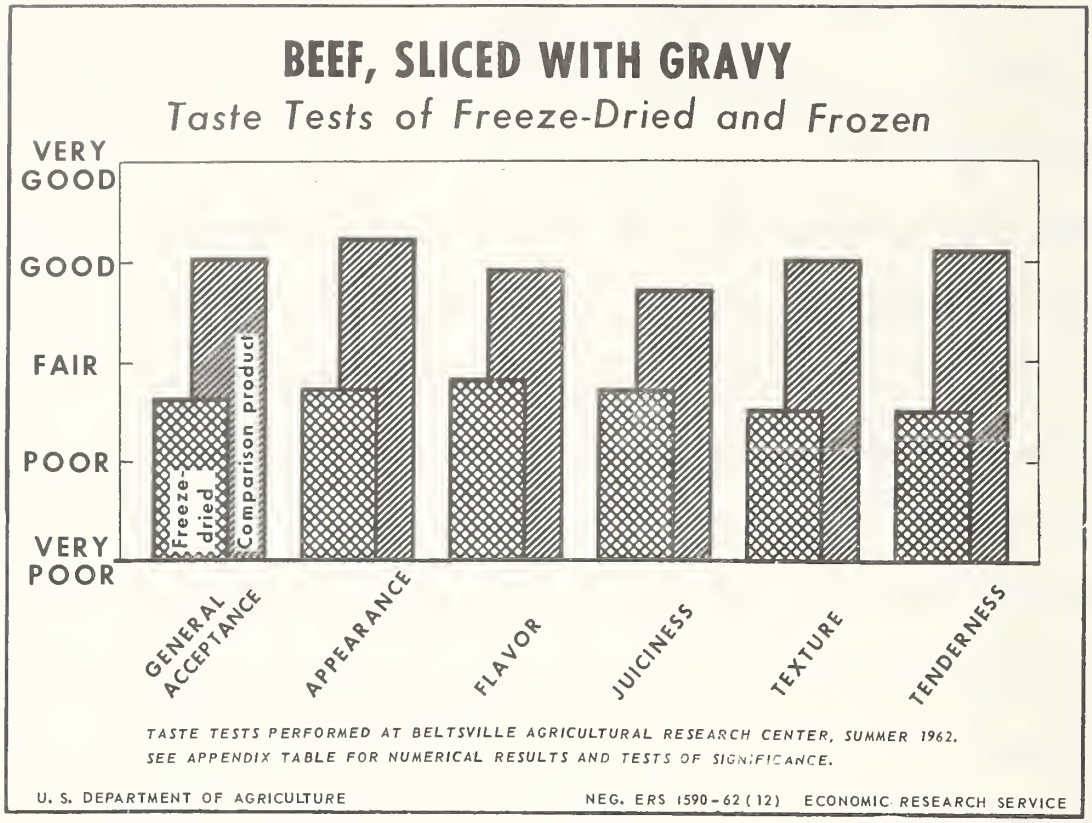
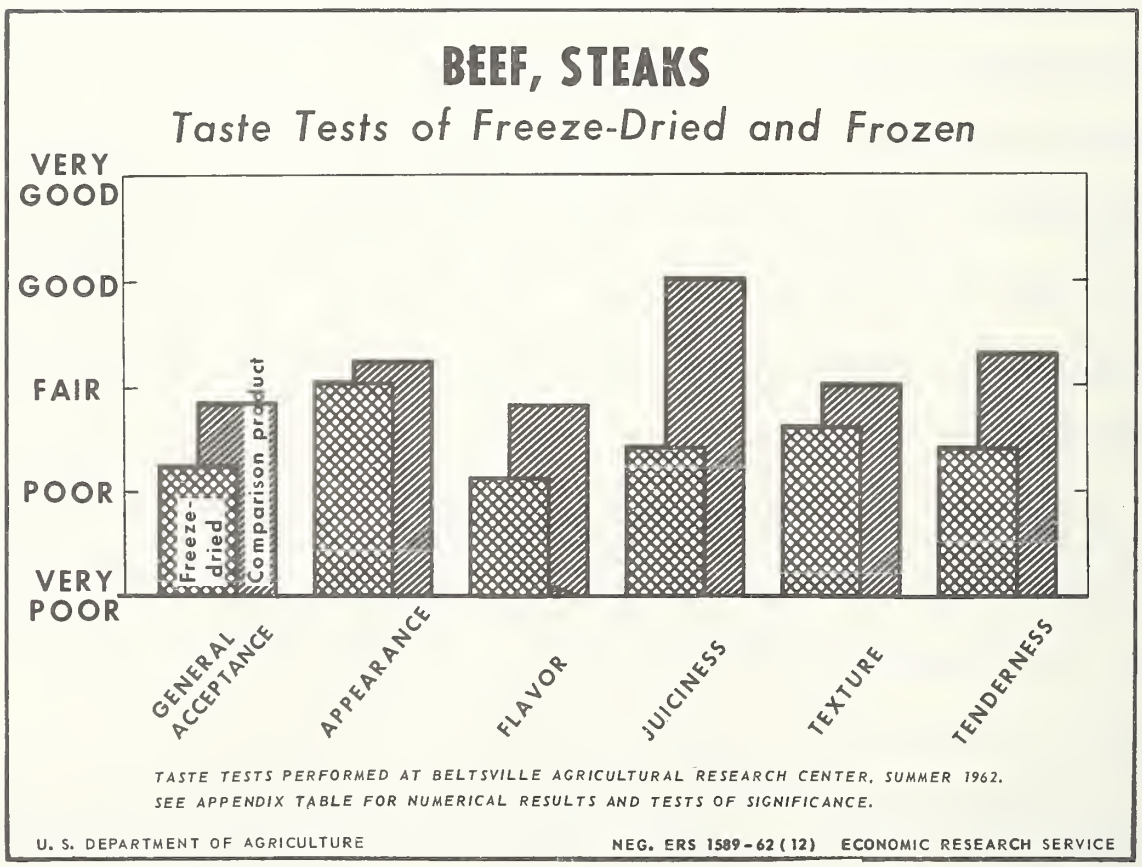


Figure 1



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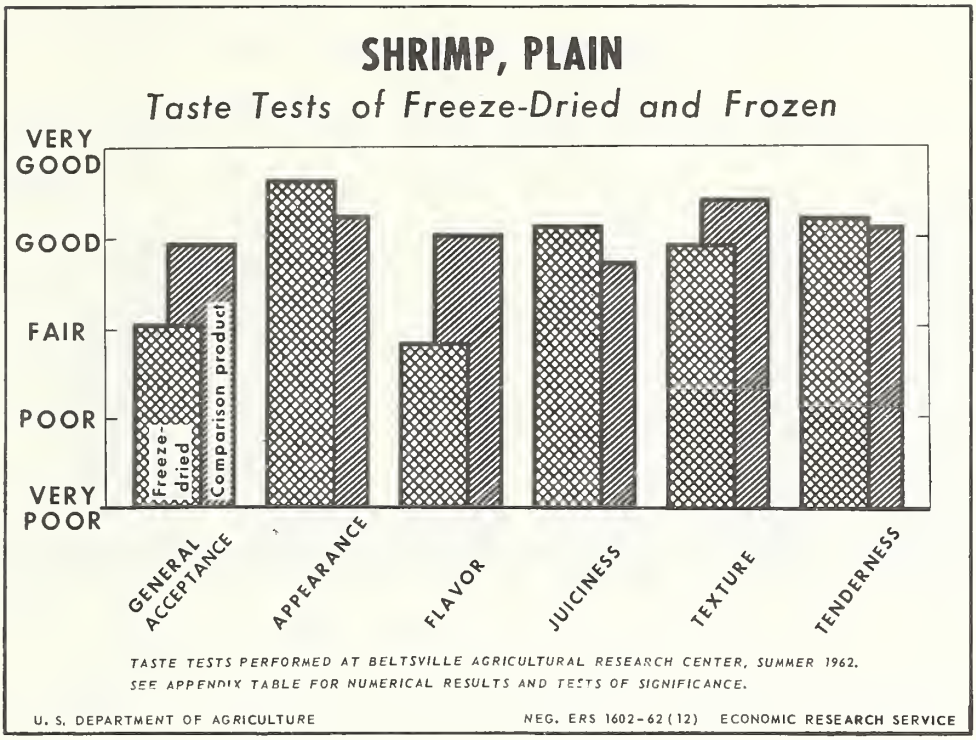

Figure 3

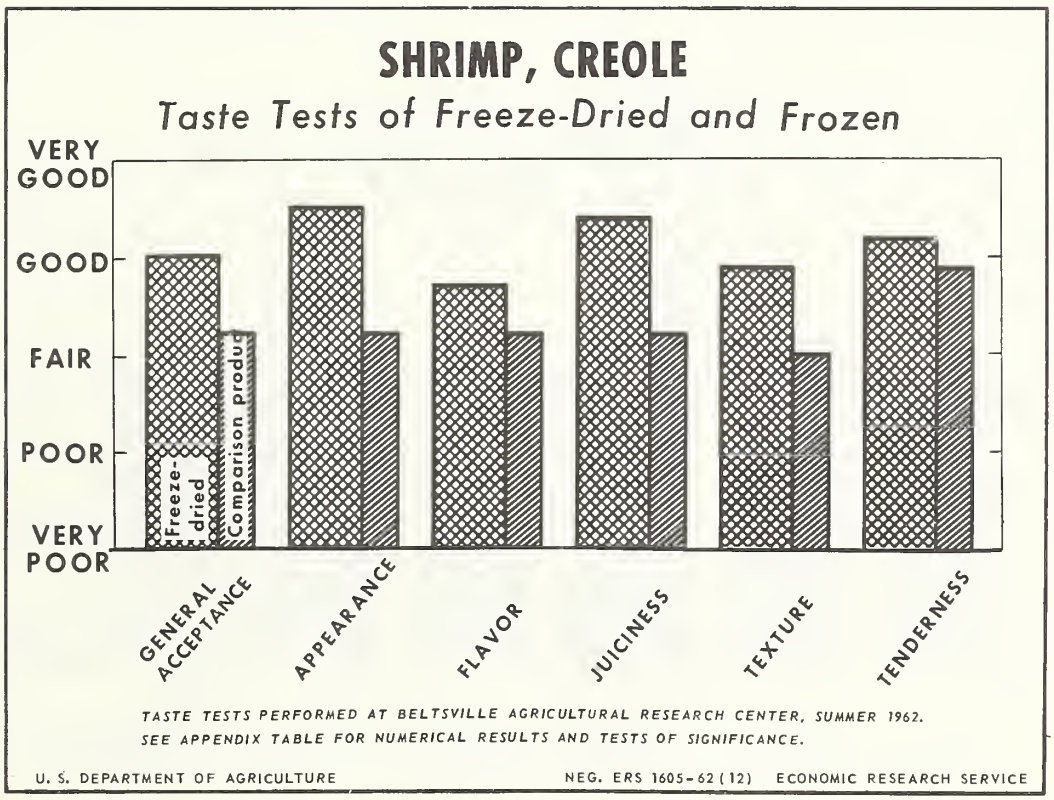

Figure 4

are from this study. In the research work of our experienced panel, we compared a freeze-dried food with the same food that had been processed in the same manner except that it had been processed another way rather than freeze-dried. For each comparison, we examined a number of palatability characteristics including appearance, flavor, juiciness, texture, tenderness, and general acceptability. In the examples given here we will look at some freeze-dried versus frozen comparisons.

Freeze-dried beef steaks received lower scores for tenderness and juiciness than the frozen beef steaks with which they were compared. In other palatability characteristics the two beef products were similar (figure 1). Freeze-dried steaks were described by panelists as being "watery or mushy" and "dry, yet oozing juice." Authorities in the field tell us that rehydration is a major problem in freeze-drying of meats. 4/

Another product tested was cooked, sliced beef with gravy. We found panel scores were low when compared with frozen, cooked, sliced beef scores (figure 2).

In all palatability characteristics, the freeze-dried swiss steak received palatability scores almost identical to frozen swiss steak. Adverse comments of both cooked, sliced beef and swiss steak were "stringy," "fibrous," and "dry." (See figure 3)

Among our seafoods tested, six were compared with frozen seafoods. These were plain shrimp, shrimp prepared into a salad in the

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4/ See "Freeze-Drying of Meats: Where It Stands and Where It Is Going," John F. Maguire of F.J. Stokes Company. Talk to the Sixth Annual Meat Sciences Institute, Rutgers University, August 20, 1963.

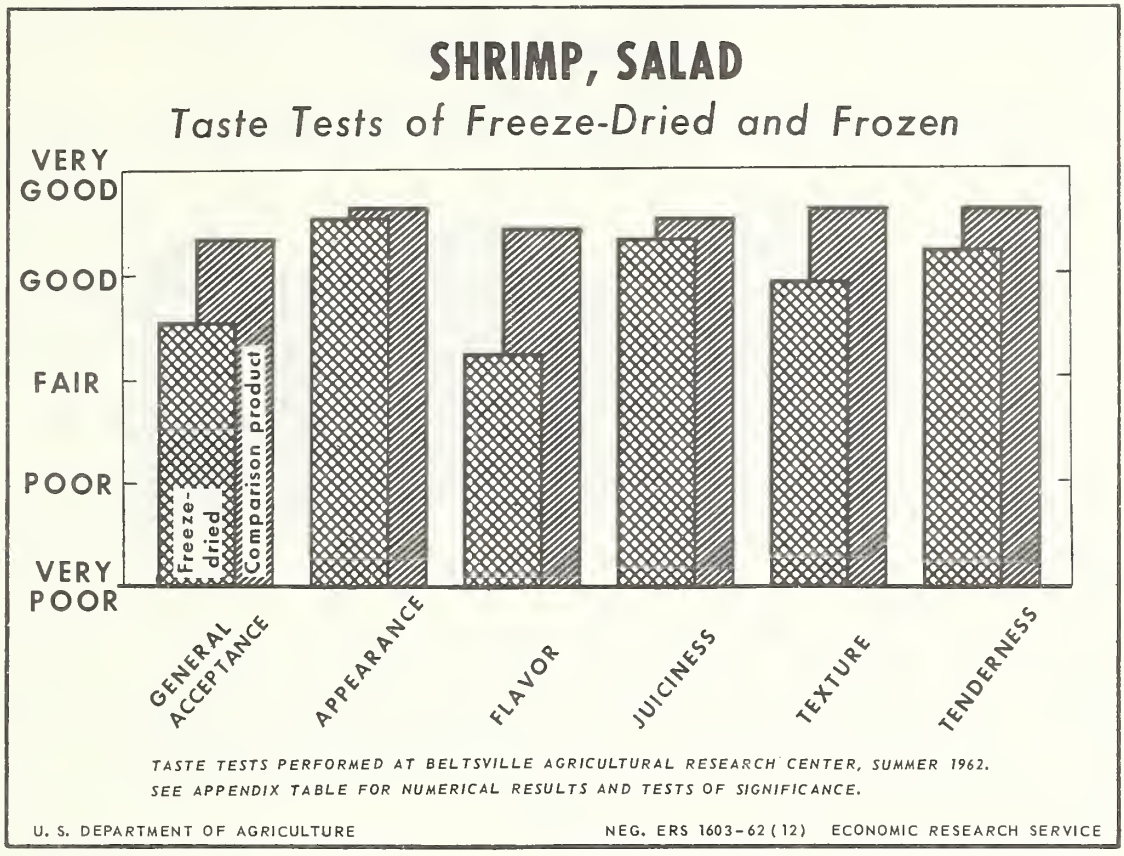
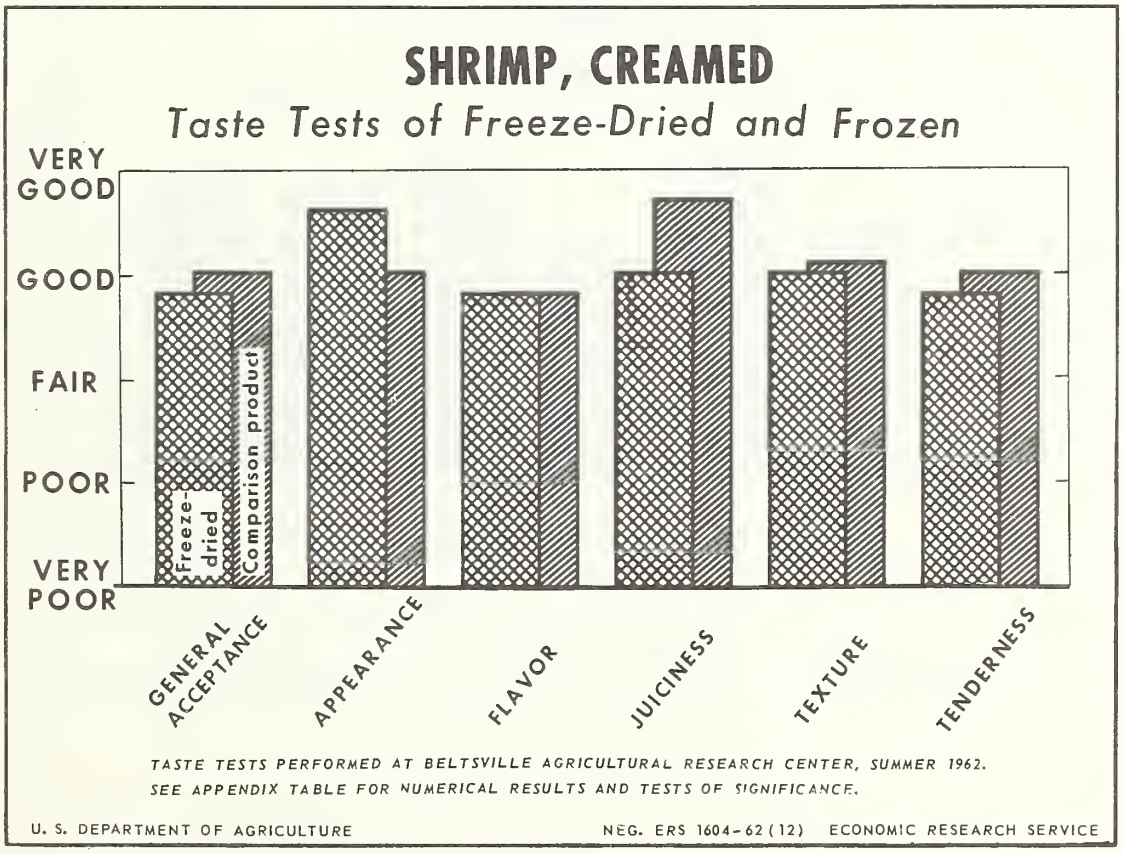


Figure 5



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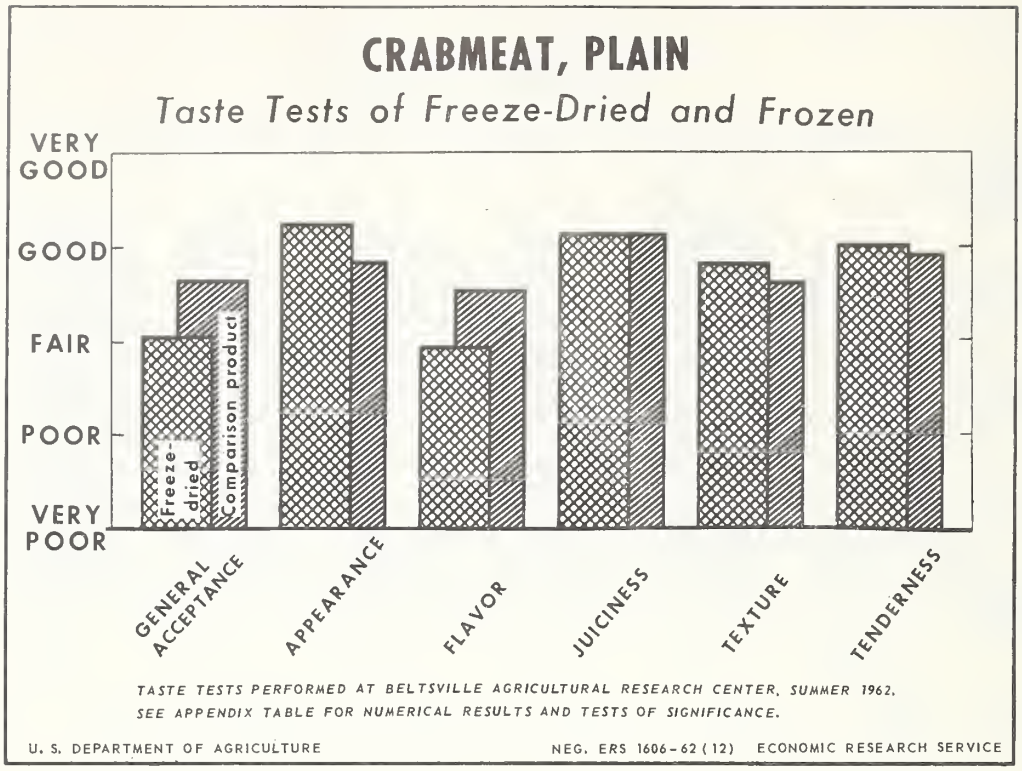

Figure 7

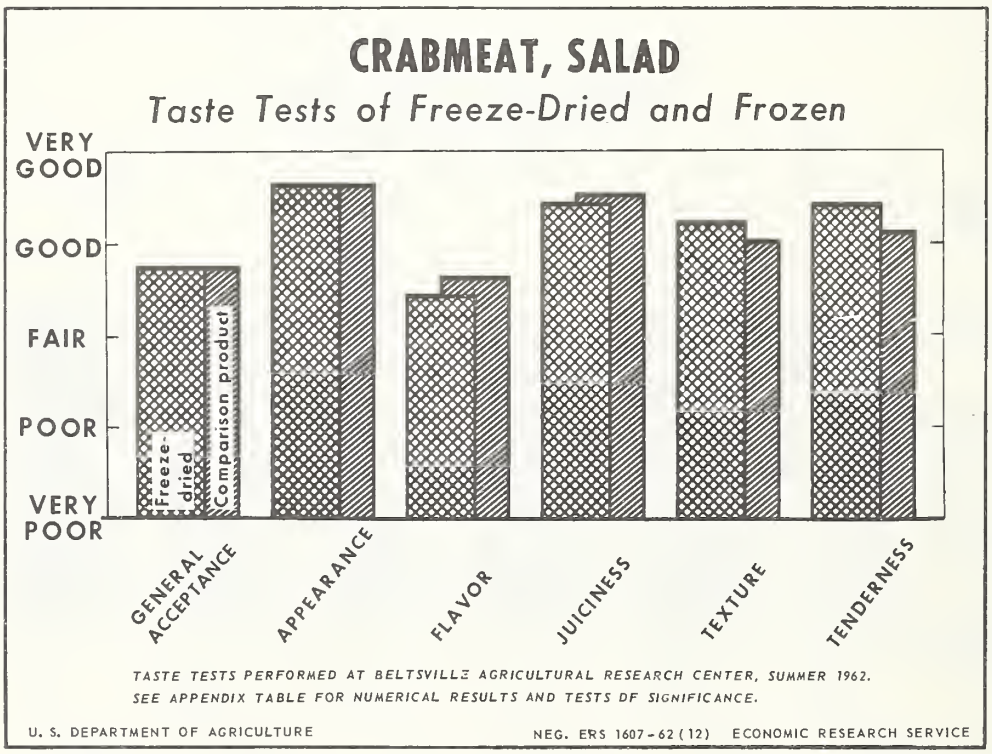

Figure 8

laboratory, shrimp made into a creamed dish in our laboratory kitchen, and shrimp creole prepared as a mix in the processing plant. Also there were crab meat, and crab meat made into a salad in our laboratory. Shrimp was one of the first freeze-dried foods entered on the institutional market, and since has grown in popularity. Shrimp creole, however, is available only in a camp pack.

We found plain freeze-dried shrimp to be about the same palatability level as plain frozen shrimp (figure 4). The main difference between the two products was in flavor, which may also have adversely affected the "general acceptability" score. In both taste characteristics, freeze-dried shrimp served plain was inferior to the frozen shrimp. In spite of the low flavor scores of the freeze-dried shrimp, our panelists made no adverse comments regarding this food.

Preparing shrimp salad from the plain shrimp had the effect of raising both "flavor" and "general acceptability" ratings (figure 5). We surmise that the addition of salad ingredients added flavor that had been lacking in the plain freeze-dried product. Creamed freeze-dried shrimp was the same palatability quality as creamed frozen shrimp (figure 6). As with the shrimp salad discussed above, flavoring ingredients covered up the flavor absence discernible in the plain freeze-dried shrimp.

Freeze-dried shrimp creole taste scores were equal to or higher than frozen shrimp creole scores (figure 7). From our research work, we concluded freeze-dried creole was superior to the frozen creole tested in all palatability aspects except in flavor and tenderness, where the two products were equal.

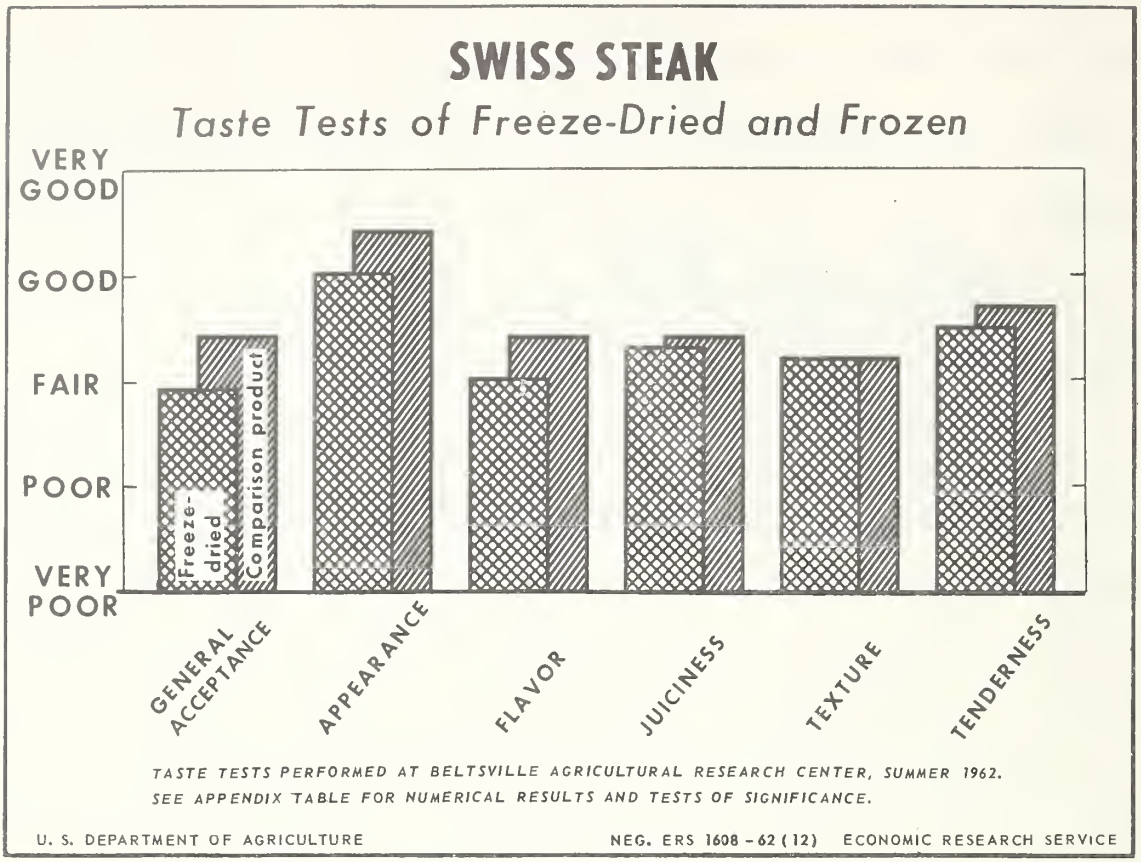

Figure 9

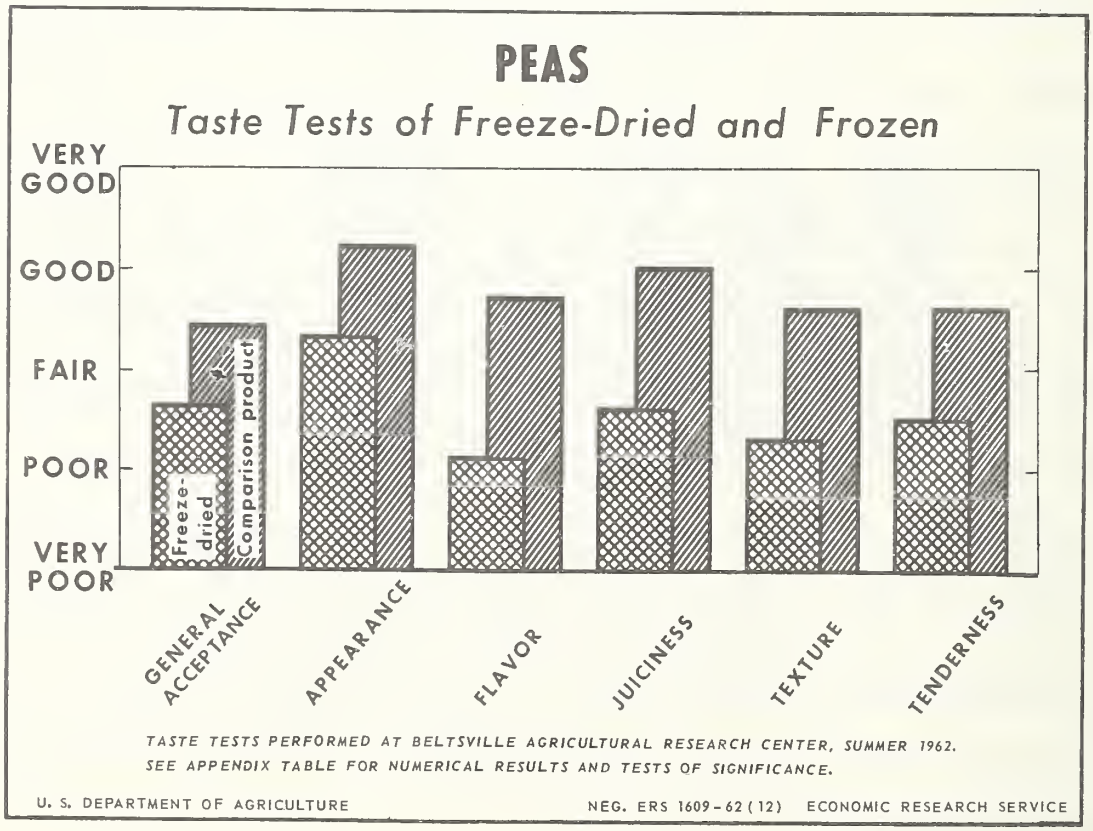

Figure 10

Freeze-dried crab meat was judged by the panelists as being equal in quality to frozen crab meat (figure 8). This was true for all palatability characteristics. As with shrimp served plain, flavor appeared to be the factor in which the freeze-dried crab was weak. As with shrimp, this weakness also was evident in the "general acceptability" scoring.

The same crab product that had been served plain was also laboratory-prepared as a crab salad and served to panelists. As with shrimp, "flavor" and "general acceptability" scores improved when crab was part of a prepared dish (figure 9). All scores of this freeze-dried crab meat were high and comparable to socres of the salad prepared from frozen crab.

Freeze-dried peas palatability scores were lower in all aspects than frozen peas (figure 10). In most flavor characteristics, these freeze-dried peas were judged as being between "poor" and "fair." Freeze-dried peas were criticized by panel members as "tough," "having tough skins," and "dry and mealy."

In looking at the whole group of freeze-dried foods, we reach the conclusion that of the 10 freeze-dried products compared with frozen foods beef steaks, swiss steaks, creamed shrimp, shrimp creole, crab, and crab salad were acceptable. No food tested was rated as "unacceptable." Freeze-dried foods used in prepared mixtures received higher scores than the same foods served plain. On the basis of ratings by this experienced panel, freeze-dried foods appear to have some prospects for volume production. Their chief market, however, may be in competition with conventionally-dried foods since

their lack of palatability seriously limits their competitive aspects relative to frozen foods.

Costs of Freeze-Dry Processing

Costs of freeze-dry processing depend upon many factors. Of first importance is the size or capacity of the plant doing the drying. The way a plant operates also is important. Length of season, hours per day, length of drying cycle, wage rates, utility rates, moisture of the product to be dried, and assumptions concerning ways costs are handled have been found important. Information concerning freeze-dry costs is derived from work done in USDA during the past year.

Table 1 shows estimates of capacity, investment, and processing costs of a typical freeze-drying plant. Figures within this table do not refer to any particular firm's operation. This plant is hypothetical and has an assumed capacity of evacuating 8,000 pounds of water per day when run 24 hours per day. If this plant were handling cooked beef (60 percent moisture), the frozen product input would be about 13,973 pounds. Dried output of this plant is 5,793 pounds. Shelf capacity of its cabinets is 2,500 square feet. This example plant is approximately the size of several of the larger plants now operating in the United States.

Investment for a plant this size is about $423,000. Most of this is in freeze-drying equipment, $375,000. Annual fixed costs for this plant are about $90,000 which includes 14 percent depreciation on equipment. Also included are building fixed costs, office

TABLE 1: ESTIMATES OF CAPACITY, INVESTMENT, AND COSTS OF A TYPICAL FREEZE-DRYING PLANT

Capacity:	
Daily volume of frozen cooked beef of 60% moisture (lb.)	13,793
Daily volume water evacuated (lb.)	8,000
Daily volume of freeze-dried beef (lb.)	5,793
Shelf space in drying cabinets (sq. ft.)	2,500
Capital Investment:	**Dollars**
Freeze-drying equipment @ $150 per square feet of shelf area	375,000
Other equipment	4,575
Building and land, 2700 square feet of building @ $16 per square foot	43,200
Total Investment	422,775
Annual Fixed Costs:	
Freeze-drying equipment depreciation @ 14% annually	52,500
Other costs of freeze-drying equipment	24,375
Costs of equipment other than drying	824
Building @ 10.2%	4,406
Office rent, 120 sq. ft. @ $3.50/year	420
Fixed utilities	600
Salaries of manager, secretary, clerk plus their fringe benefits that are paid in cash	6,840
Total fixed costs	89,965
Variable costs per day when plant operated 24 hours per day	
Labor: operator, 24 hours @ $2.06	49.44
assistant operator, 12 hours @ $1.73	20.76
product weighers, 15 hours @ $1.68	25.20
tray men, 8 hours @ $1.68	13.44
tray washers, 8 hours @ $1.68	13.44
department foremen, 6 hours @ $3.96	23.76
maintenance men, 8 hours @ $2.20	17.60
janitor and cleanup 3 @ $1.63	4.89
quality control 2.4 @ $1.77	4.25
Total labor, 86.4 hours	172.78
Labor fringe benefits @ 14%	24.19
Total costs of labor	196.97

TABLE 1 (cont.)

Utilities: (Per day)	
Electricity, 3520 KwH @ .015/KwH	52.80
Steam, pounds used for heat of sublimation and defrosting 20,000 pounds, used in vacuum pumping 40,000 cost @ $.80 per 1000	48.00
Nitrogen, 4000 cu. ft. @ .008/cu.ft	32.00
Water and sewerage @ 48,000 gal/day (water for steam jet condensers recirculated through water tower)	.96
Heat, lights, and miscellaneous utilities	1.00
Total Utilities (Per day)	134.76
Miscellaneous Variable Costs	6.09
Total variable costs per day	337.82
TOTAL COSTS PER YEAR	157,529
Average costs:	
Per pound of input product (frozen food)	.05
Per pound of water evacuated	.10
Per pound of output product (dried food)	.12

Specifications and assumptions: Plant operates 24 hours per day and 200 days per year. Cooked beef is assumed the only product and has 60 percent moisture in frozen state and 2 percent in dried state. Ten-hour drying cycles used. Food loaded 2.75 pounds per square foot of shelf area. Wage and utility rates are assumed representative of a small-sized city in the East.

rent, utilities that do not vary with volume, and salaries of management and clerical staff.

Variable costs per day for this plant include labor, utilities, and miscellaneous. Table 1 shows a listing of the number of hours for each worker in the plant, wage rate of each worker, and the total cost of labor for this plant as operated 24 hours per day. Labor costs are $197 per day. Electricity costs are $53 per day. Steam, which is used both for providing heat for sublimation and in water evacuation with steam jets, is $48 per day. Nitrogen, used for breaking vacuum in the cabinets, is $32 per day. Other utilities, including water and sewerage, are $2 per day. Variable costs total $338 per day.

Processing costs per year for this hypothetical food freeze-drying plant are $157,000. Put on a basis of water evacuated, these costs are $.10 per pound. Relative to pounds of input product, costs are $.05 per pound. Costs related to the dried product are $.12 per pound. In all of these costs, we are assuming that the plant would operate 200 days per year and a 10-hour drying cycle would be used. 5/

5/ Because of high costs and relatively small volumes, prices of freeze-dried products are high. As an example, mushrooms sell at about $10 to $12 per pound of dried weight. Peas and corn that have been freeze-dried sell in wholesale channels at $1.50 to $2.25 per pound. Green beans, strawberries, and peaches currently sell at about $4.00 to $6.00 per pound of dried weight. Asparagus, apricots, and cocktail mixes wholesale at $6.00 to $8.00 per pound. Cottage cheese is about $2.50 per pound of dried product. Meats may sell as high as $10 to $12 per pound of dried product. Another important reason for high prices of these foods is the ratio of finished product to incoming product. As an example, let us suppose that 100 pounds of pork chops were to be processed by a freeze-drying plant. The processor trims off all the fat and bone and ends up with 60 pounds of lean meat.
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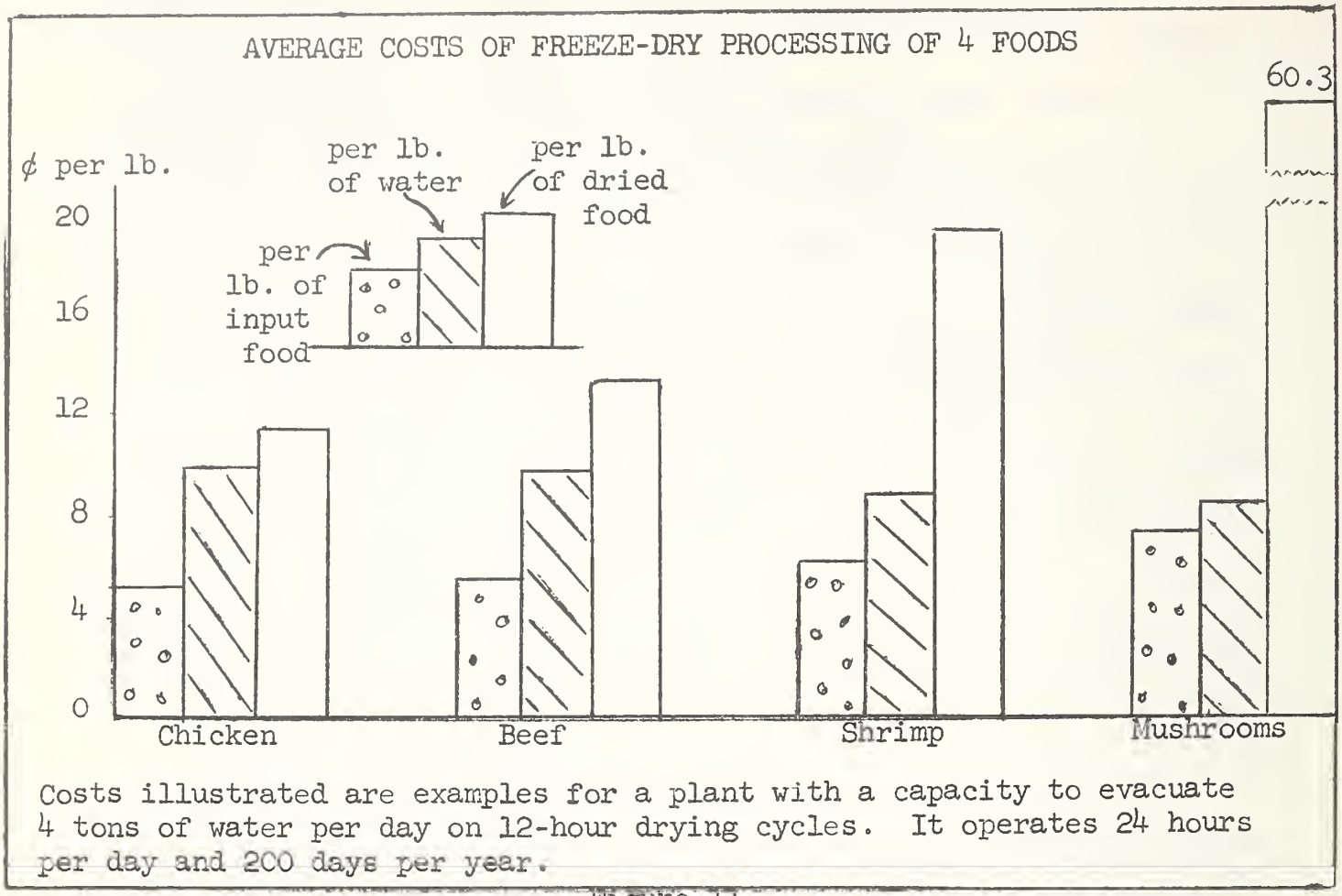

Figure 11

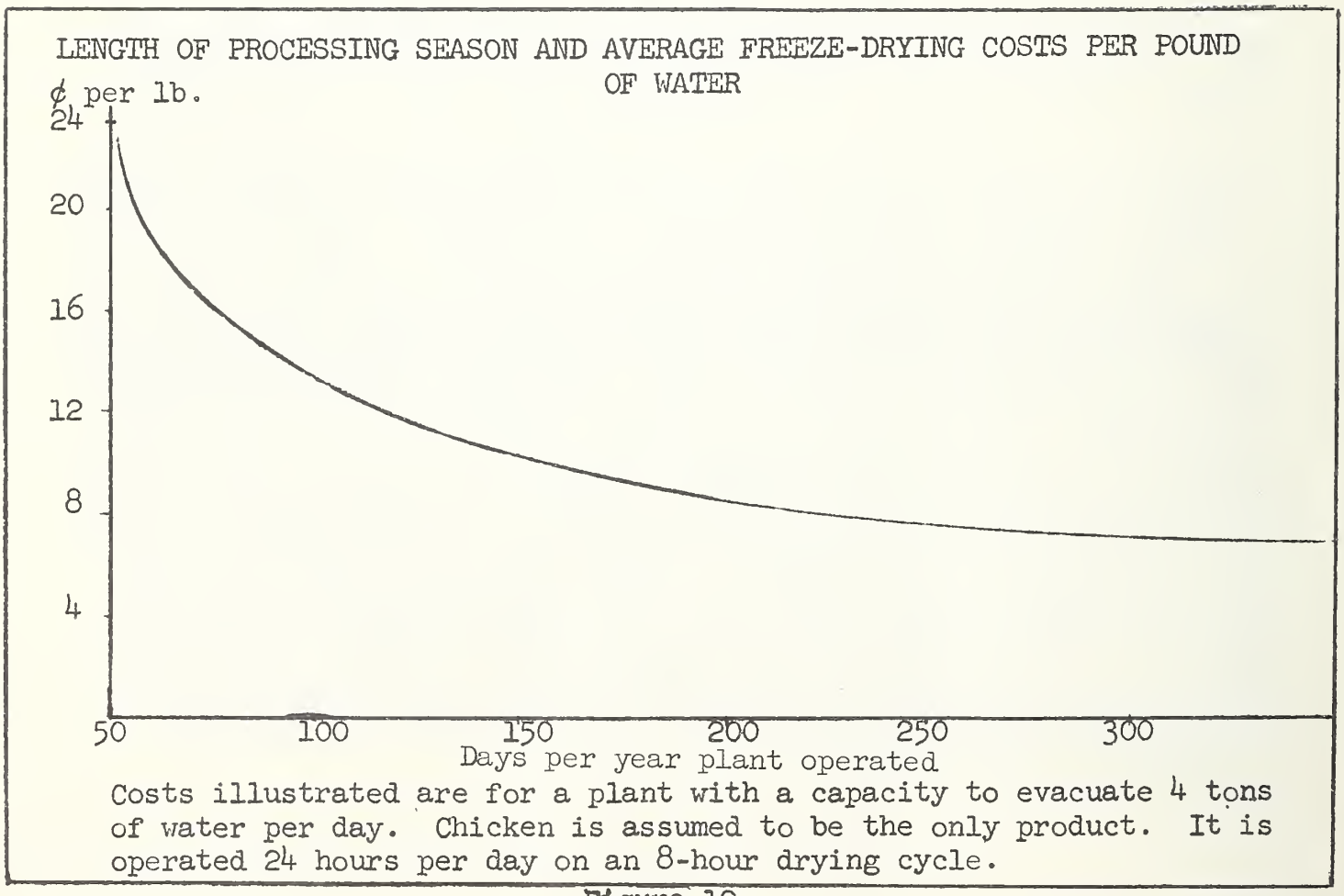

Figure 12

Costs may be lowered by operating this same plant on shorter drying cycles. Some plants now in commercial operation are on a 8-hour cycle. Others have longer cycles, with correspondingly higher costs.

Costs for various products being dried depend largely upon the percentage of moisture in the frozen food. Figure 11 shows costs for four products. In the illustration, average costs are calculated three ways: (1) per pound of input food; (2) per pound of water evacuated; and (3) per pound of dried food. The chicken illustrated in figure 11 is cooked in dices with 56 percent moisture. The beef is cooked and has 60 percent moisture. The shrimp has 70 percent moisture and the mushrooms 90 percent. Note the higher percent moisture of the frozen product, the higher the cost per pound of input product and the lower the cost per pound of water evacuated.

Figure 12 illustrates the effect of length of processing season on freeze-dried processing costs. In this illustration, chicken is assumed to be the only product and if this plant were operated 50 days per year, costs are $.23 per pound of water removed. Under the same conditions except that the processing year is 300 days, costs are about $.08 per pound of water.

5/cont. This meat is sliced, cooked, and frozen and is now 50 pounds. If the frozen cooked lean pork meat is 53 percent moisture, and the end product is to be dried to 2 percent moisture, the weight of the dried product is about 25 pounds. This is $\frac{1}{4}$ of weight of the input product. If there were no processing costs involved, the equivalent price of the pork, as dried would be 4 times the beginning price. So a fifty cent per pound pork chop is now a $2.00 per pound item. Add to this the costs of trimming the meat, the cooking, slicing, freezing, drying, and packaging and costs rise to levels that are high.

Costs of larger plants have been synthesized in our cost study, and we find that plants with a throughput of about 40 to 50 tons of frozen food per day have costs as low as $.03 to $.05 per pound of water removed, if operated at full capacity. Lower costs than these are foreseen as shorter drying cycles and other innovations are used. A flow-dryer, if developed, might reasonably be expected to yield processing costs of $.03 per pound of water removed.

Expected Freeze-Drying Volumes

In a new industry such as freeze-drying, it is improbable that volume projections have a high degree of accuracy. With this caution in mind we estimate that about 250 million pounds of food will be freeze-dried in 1967. These pounds are in fresh-weight equivalent. If it takes 1.8 tons of refrigeration to blast-freeze 100 pounds of product per hour, we might expect the refrigeration capacity of the country to increase about 2,250 tons. 6/ This assumes that present freezers are not available for use, and that the new ones would be used 2,000 hours per year.

In addition to freezing the food to be freeze-dried, another use for refrigeration is in the sublimation process. A product with 80 percent moisture requires about 10 tons of refrigeration for each 100 pounds of product dried per hour. The plant illustrated in Table 1 has a capacity of 333 pounds of water per hour, or 433

6/ About 1.5 tons of refrigeration are needed to plate-freeze 100 pounds of food per hour.

TABLE 2: ANTICIPATED INCREASES IN REFRIGERATION NEEDS CAUSED BY FREEZE-DRYING INDUSTRY IN 1967

Expected yearly volume of freeze-dried foods in 1967 (million pounds of frozen food)	250
Number of freeze-drying plants each with 4 tons per day water evacuation capacity needed to handle above product	104
Tons of refrigeration needed for freezing foods to be freeze-dried @ 1.8 tons per 100 pounds product dried per hour (2000 hour year)	2,250
Tons of refrigeration needed for sublimation of above volume @ 10 tons per 100 pounds product to be dried per hour*	10,000
Total new tons of refrigeration needed for freezing and sublimation of freeze-dried foods	12,250
Investment costs of refrigeration per plant using investment cost of $1,400 per tons of refrigeration (Freon system)	$57,120
Investment in refrigeration for the freeze-drying industry (million dollars)	$17

* In sublimation there are 1,074 BTU's per pound of water as latent heat of condensation. It takes 22 BTU's to sub-cool from 32°F to 10°F, and 144 BTU's as latent heat of fusion from water to ice. These total 1,240 BTU's per pound of water sublimated. The plant described above has a water evacuation capacity of 333 pounds per hour so 1,240 BTU's times 333 pounds of water equals 413,333 BTU's needed per hour. There are 12,000 BTU's per ton of refrigeration so 34 tons of refrigeration is the theoretical need. A 20 percent loss factor added in makes the refrigeration capacity needed, 41 tons. If the product being dried has 80 percent moisture, the flow of frozen input product is 412 pounds per hour (333 ÷ 80 percent). Thus, 10 tons of refrigeration are needed for each 100 pounds of product to be dried.

In calculating industry tonnage needs, we estimate each freeze-drying plant will operate 2,500 hours per year, so the flow of frozen product is $\frac{250,000,000}{2500}$ = 1,000 cwt/hour.

If 10 tons of refrigeration are needed for each 100 pounds of food sublimated per hour, 10,000 tons of refrigeration are needed in sublimation for the industry in 1967.

pounds of 80 percent moisture input product per hour. This plant would require about 43 tons of refrigeration for use in sublimation. 7/

For purposes of illustration we again assume the freeze-drying industry will process 250 million pounds of frozen product per year and estimate the industry requirements for refrigeration needs. New refrigeration tonnage for both freezing and sublimation are 2,250 tons and 10,000 tons respectively. If we place an investment price of $1,400 per ton of refrigeration, new refrigeration investment of the industry is $17 million, Table 2.

Freeze-Drying and the Frozen Food Industry

Effects of the freeze-drying industry on the frozen food industry may be summarized as follows: (1) For the most part, freeze-dried foods do not have the quality of frozen foods. There are exceptions to this, usually in specific products where the quality of the frozen food is low. Thus, it is not expected that freeze-dried foods will replace frozen foods to any great extent in our marketing system. (2) Costs of freeze-dry processing are now about $.08 to $.15 per pound of water. In the future, they may decline to a range of 4 to 8 cents per pound of water or about 3 to 7 cents per pound of frozen product. Even these costs are high though, relative to costs of freezing alone, and high costs may be an important factor

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7/ In this country, it is common practice to use mechanical pumps and refrigerated condensers for water evacuation. To my knowledge, there is only one steam-jet plant in operation in the United States. In Europe, however, steam jets are commonly used. They depend upon a plentiful supply of cold water. Although they have a lower investment cost, they have high operating costs. Maintenance costs are high with a mechanical pump system and low with steam jets.

in keeping freezing from achieving volumes now enjoyed by our food canning and freezing industries. For comparison purposes, the present refrigeration tonnage of the food freezing industry in this country may be estimated as follows: In 1961 the volume of farm foods frozen by commercial freezers (excluding seafoods, prepared meals, and frozen dairy products) amounted to 6.7 billion pounds. This is composed of fruits and juices, including concentrates, 1.7 billion; vegetables, 2.3 billion; poultry meats, 2.3 billion; and red meats, 0.4 billion pounds. Frozen fishery items pertain to the 1962 catch and are in terms of millions of pounds: Shrimp 78, other shell fish 9; ocean perch 26; haddock 11; other blocks, fillets, and steaks, 19; halibut 43; whiting 34; salmon 15; other round and dressed fish 45; bait and animal food 63. These frozen fish total 343 million pounds. In 1961 canned food processed in the United States (excluding seafoods, prepared mixes, and pet foods) was 19.3 billion pounds as follows: Fruits and juices, including pineapple, 2.8; vegetables 8.8; poultry meats 0.6; and red meats 2.4. In 1962 canned fishery items were 1,097 million pounds as follows: Tuna 34.4; salmon 18.2; Eastern sardines 50; Pacific sardines 5; mackeral 54; crab 8; shrimp 14; clam 9; diced clams 15; oysters 4; fish, used as animal food 374; other 38. These total 7.04 billion pounds of frozen food and 20.4 billion pounds canned food. 8/

8/ The above figures were obtained from the following sources: Fruit, vegetable, poultry, red meat from various commodity analysis branches of the Economic and Statistical Analysis Division, ERS, USDA. Fishery estimates were made by the Bureau of Commercial Fisheries, U.S. Department of Interior, Washington, D.C.

Our 250 million pound estimate of freeze-dry production is about 4 percent of present frozen food volumes and 1 percent of present canned volumes. (3) Freeze-dried foods require refrigeration in both freezing the foods and in the sublimation of them. 9/ Every pound of food to be freeze-dried must be frozen in a conventional manner. 10/ Then sublimation uses refrigeration. These two uses require about 11.8 tons of refrigeration per 100 pounds of food frozen and dried. (4) If 250 million pounds (frozen equivalent) of freeze-dried foods are processed in 1967, the refrigeration needs of the country will be increased by about 12,250 tons. Assuming this would be additional refrigeration, new investment in refrigeration equipment would be $17 million between now and then.

9/ We may estimate the present refrigeration tonnage of the country being used in food freezing. Volumes of frozen food are now about 7.04 billion pounds. If the plants freezing this food operate 2000 hours per year this is a flow of 35,215 cwt per hour. Using our rule of thumb of 1.8 tons of refrigeration for each cwt of food frozen per hour, there are now 63,387 tons of refrigeration being used to freeze the food output of the frozen food industry. This does not include refrigeration tonnage used in maintaining, transporting, or refreezing of these foods. Nor does it include grocery store food cases, home freezers, locker storage, air conditioners, or other uses for low-temperature equipment.

10/ An exception to this is vacuum freezing. Here the product is placed in a cabinet, frozen by lowering the pressure, and then the usual sublimation process is initiated. This is currently being done in a Canadian plant for mushrooms. It is not true freeze-drying since the vacuum freezing process draws out about 20 percent of the moisture and shrinks the food.

Equipment now being designed in France allows for food freezing by conventional means in freeze-dry cabinets. This latter system would be classified as true freeze-drying, even though here, too, the food is frozen in the freeze-dry cabinets.

If you are interested in receiving other freeze-dry reports write to: Division of Information, Office of Management Services, U.S. Department of Agriculture, Washington, D.C. 20250. At present, about ten different reports are available. All are free.